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METHODS AND COSTS OF DREDGING AURIFEROUS GRAVELS AT LANCHA PLANA, AMADOR COUNTY, CALIF.

BY

CHARLES G. PATMON

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METHODS AND COSTS OF DREDGING AURIFEROUS GRAVELS AT LANCHA PLANA, AMADOR COUNTY, CALIF.[1]

By Charles G. Patmon[2]

INTRODUCTION AND ACKNOWLEDGMENTS

This paper describing the methods of dredging and treatment of gold-bearing gravels at the Lancha Plana Gold Dredging Co.'s dredge is one of a series of similar papers being prepared by the Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States.

The dredge is located near the Mokelumne River, 12 miles west of San Adreas, Calif.; it is accessible by an improved dirt road from Jackson, which is about 20 miles distant.

The dredge herein described is the only one operating in Amador County at present. It has operated continuously since July, 1929. The Lancha Plana Gold Dredging Co. owns a total of 75 acres, of which 37.02 acres have been dredged to date (Sept., 1931). The total yardage handled during this period has been 1,436,603 cubic yards. The dredge has a capacity varying from 80 to 200 cubic yards per hour, depending on the character of the material being dug and treated. The dredge is of the continuous-bucket type with a nominal capacity of 6 cubic feet per bucket. Operations are conducted on a 24-hour basis with a crew of two men on each of the three 8-hour shifts; three additional men on the day shift are required. The climate is mild and dredging can be done the year around without any hindrance from climatic conditions.

The author acknowledges the assistance of William O. Vanderburg, associate mining engineer, and Charles H. Johnson, assistant mining engineer, U. S. Bureau of Mines, in the preparation of this paper.

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6659."

2 - One of the consulting engineers, U. S. Bureau of Mines, and General manager of Lancha Plana Gold Dredging Co.

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HISTORY OF THE DISTRICT

The ground comprising the holdings of the Lancha Plana Gold Dredging Co. is on the site of the former mining town of Lancha Plana, which in 1850 had a population of about 3,000. In the early days the river bars and benches were worked for the recovery of gold by hydraulic and hand methods.

Dredging operations were first started in the district in 1904. From 1916 to 1923 was the period of greatest dredging activity, when the American Dredging Co. operated three dredges on the Mokelumne River from the site of Lancha Plana downstream for 9 miles. Part of this ground was in Amador, part in Calaveras, and part in San Joaquin Counties. The gravel was from 6 to 35 feet deep, averaging 20 feet, and carried considerable overburden. Two of the dredges operated by this company were equipped with 6-cubic foot capacity buckets, and the third with a 9-cubic foot capacity bucket. The smaller dredges each handled about 125,000 cubic yards monthly and were found better adapted to the comparatively shallow ground than the larger one. The company held a total of 450 acres of land and the average width of the channel dredged was about 400 feet. The cost of this dredging averaged a little less than 10 cents per cubic yard. The American Dredging Co. ceased operating in 1923, and there was no further activity in the district until July, 1929, when the Lancha Plana Gold Dredging Co. commenced dredging. This company was organized in 1927.

GEOLOGY

The topography of the dredging area (fig. 1) is gently undulating, and the surface is not covered with timber or stumps to interfere with digging operations. The deposit consists of an old river channel having an average width of 300 feet at the site of present operations. The depth of the gravel varies from 20 to 40 feet. For the year 1930 the average depth of the gravel dredged was 21.8 feet. The remainder of the acreage will average much deeper than this.

The bedrock is cut by channels which can be dredged clean only by careful operation, as the drop is abrupt when approached from the side. Such sudden drops also cause trouble owing to the difficulty of disposing of the larger amount of gravel in the shallower excavation behind the dredge. In general the ground is fairly tight, so that there is little difficulty in maintaining the water in the dredge pond. In some places the gravel is covered with a mantle of clay or sand. About 1-1/2 acres out of the 75 held by the company is covered with clay, which is very difficult to dig.

The size of the gravel ranges from sand to cobblestones and an occasional large bowlder weighing several tons. The composition of the material dredged varies from place to place. On the average it might be 40 per cent gravel and cobblestones, 40 per cent sand, and 20 per cent loam and clay. It is estimated that 40 per cent of it is removed as over-size in screening. The bedrock consists of soft altered porphyry, which affords easy digging. The average depth of bedrock dredged is about 1 foot.

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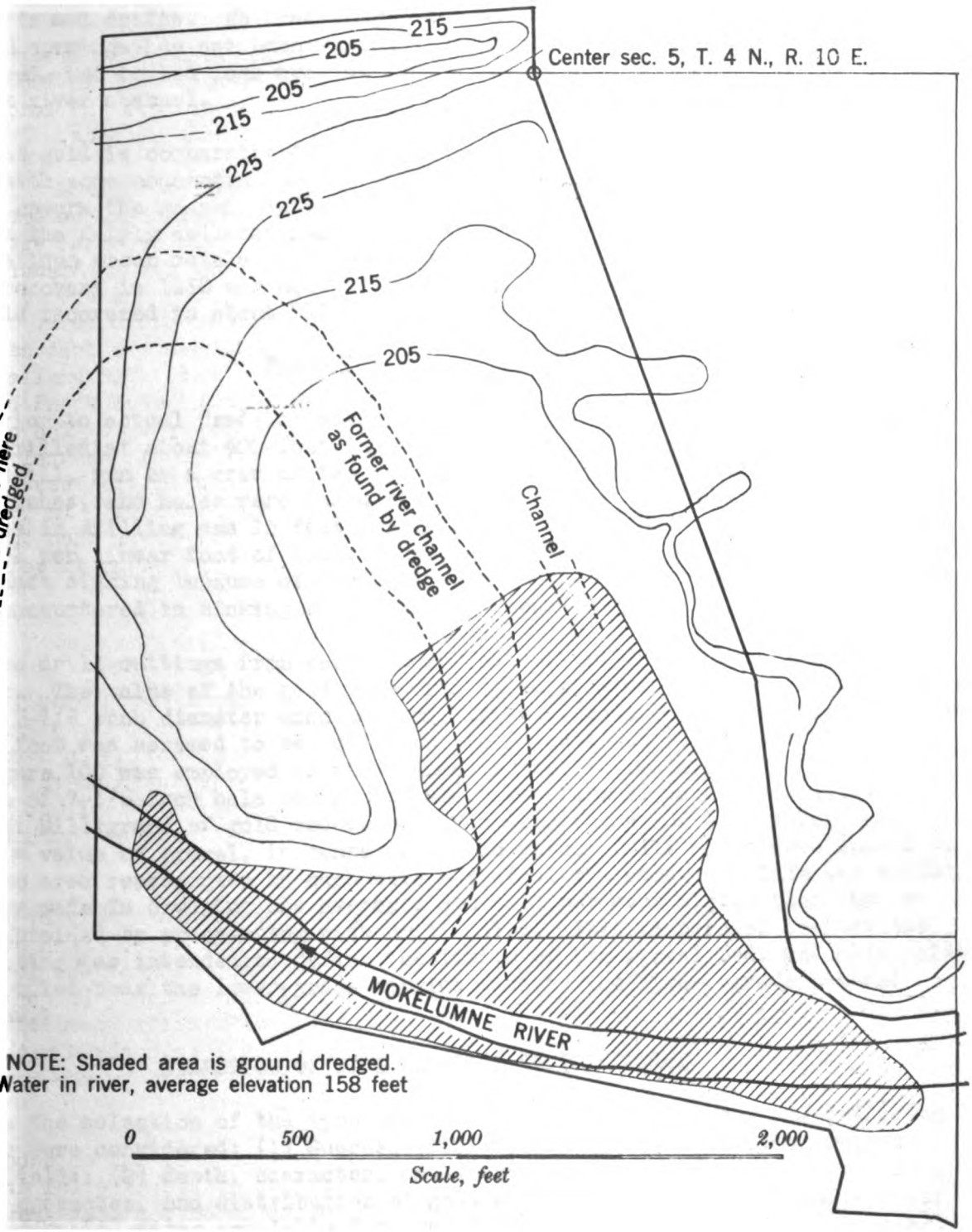

Figure 1.— Dredging land of Lancha Plana Gold Dredging Co., Amador Co., Calif.

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About half of the ground now being dredged has been partially exploited by shafts and drifts. No breasting was done, however, and the ground between the old openings has not been worked. Old mine timbers are sometimes encountered, but burned logs are not found, except some occasionally met in the present river channel.

The gold is comparatively coarse and distributed through the gravel and clay, with some concentration near and on the bedrock. The sand, which in places covers the gravel, is practically barren of gold. In general the "pay" follows the fairly well-defined channel of the old river. Small amounts of the platinum group metals are recovered in dredging; about 1 per cent of the total recovery in 1930 was equally divided between platinum and iridium. The gold recovered is about 890 fine, with 90 parts of silver on the average.

PROSPECTING AND SAMPLING

Prior to actual dredging operations by the present company the ground was churn-drilled at about 400-foot intervals by means of a gasoline-driven Keystone drill, run by a crew of two men. The diameter of the drill shoe was 7-1/8 inches, and holes were cased with 6-inch pipe. The average rate of progress in drilling was 15 feet per 8-hour shift. The drilling cost averaged about $1 per linear foot of hole. Prospecting with drills was more applicable than shaft sinking because of the depth to bedrock and the difficulties liable to be encountered in sinking shafts in wet ground.

The drill cuttings from each linear foot of drill hole were sampled by panning. The value of the gold recovered in panning was determined by weighing. With a 7-1/8 inch diameter shoe each milligram of gold (900 fine) recovered per linear foot was assumed to be equivalent to 6 cents per cubic yard of gravel. The figure 100 was employed as the volume factor, representing the theoretical footage of 7-1/8-inch hole per cubic yard. The formula used was then as follows: Milligrams of gold recovered times 0.06 times 100 ÷ feet depth of sample = value of gravel, in cents per cubic yard. Drill holes were spaced so that the area represented by each hole was about the same. To date the actual recovery made in dredging has averaged about 33 per cent higher than the results obtained by prospecting with drill holes. This is perhaps because the prospecting was intended to define the limits of the gravel bed, and more holes were drilled near the lower-grade margins than in the higher-grade central portions.

SELECTION OF TYPE AND SIZE OF THE DREDGE

In the selection of the type and size of dredge to be used the following factors were considered: (1) Success with various types of dredges used in other fields; (2) depth, character, and amount of ground to be worked; (3) value, character, and distribution of gold content; (4) character and contour of bedrock; (5) water available for dredging; and (6) amount of capital available for construction of dredge.

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The continuous-bucket dredge is practically the only type that has proved successful in the dredging fields of California, and it is the only type in use there where conditions are favorable for dredging. In consequence this type of dredge was decided upon as being the best type to construct.

From the data obtained in prospecting it was estimated that the amount of gravel available for dredging would provide a life of 8 years for the enterprise by using a dredge having buckets of 6 cubic feet capacity. As a wooden hull may be expected to last from 8 to 10 years, a hull of timber construction was selected for the reason that it would require the least amount of capital to build.

An abundant water supply for the dredge was available in the near-by Mokelumne River, and the height the water had to be lifted was not excessive.

In general the 6-cubic foot capacity bucket dredge was considered the most economical to construct and operate under the conditions presented, and this size would allow a good profit on the money invested after allowing for the amortization of capital.

DETAILS OF DREDGE CONSTRUCTION

The dredge in use by the Lancha Plana Gold Dredging Co. is a Link-Belt dredge of standard design, with a total displacement of about 1,000 tons. It does not differ from the ordinary continuous-chain bucket dredges used for other work so far as the digging part is concerned, except that the strength and weight of the digging ladder assembly have been increased to withstand the rougher usage to which gold dredges are subject.

The essential parts of the dredge consist of a hull, a digging ladder assembly, screen, sluice boxes and riffles, a stacker, pumps, and lines and spuds to hold the boat in position while digging, with the necessary drive motors for each part where power is required.

The hull was built locally of clear No. 1 grade Douglas fir timbers at a total cost of $28,500, without machinery. The dredge machinery was purchased second-hand; it was formerly used on the El Oro No. 3 dredge which operated in the northern part of California. As shown in Figure 2, the hull is rectangular in shape, 98.5 feet long, 41 feet wide, and draws 5 feet of water. The deck of the hull is 3 feet above the water line when operating. To allow the digging ladder and the chain of buckets to descend to the bottom of the ground to be worked, the forward part of the hull is divided by an opening called the "well" in which the digging ladder is free to move either up or down on pivotal bearings.

The bow of the hull is narrow and the pontoons are cut on long radius curves on the outside for the purpose of avoiding interference with the bank when digging on corners. With a long digging ladder which would project a considerable distance in front of the hull the bow of the boat could be built square and thus obtain more displacement at this point where much of the weight is concentrated.

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To withstand the strains to which the boat is subjected when digging, the hull is strengthened by trusses running in both directions beneath the deck. The dredge floats slightly higher at the bow than at the stern, so that bilge water drains to the stern, where it is pumped out by an electric pump.

Hatchways are placed in the deck to give entrance to the hull for inspection, and to allow circulation of air through the hull, which prolongs the life of the timbers.

Bucket Line and Tumblers

The digging-ladder assembly consists of a plate-girder type of frame strongly built of steel with a tumbler at either end so that the chain of buckets may travel continuously around its length. The length of the digging ladder is 77 feet 9 inches from the pivot to the outside of the digging lip on the bucket. The digging ladder is capable of describing an arc of 55° below the horizontal. The maximum depth which the dredge is able to dig below water line is 47 feet. A maximum depth of gravel of 67 feet has been dug, of which, however, 20 feet was above the water line. The digging-ladder assembly is one of the most important parts of the dredge, for upon the continuous operation of the buckets depends the economical operation of the dredge. To avoid high operating costs maximum strength consistent with proper design is essential. Even though great strength is obtained in the wearing parts of the digging-ladder assembly, still breakdowns and repairs of this part of the dredge equipment constitute the principal cause of delays. The bucket line on the Lancha Plana dredge is of the type called the "close connection"--that is, the buckets follow each other on each link of the bucket chain. This type is generally used at present in the dredging fields of the United States.

The shape and weight of the buckets are determined by the character and depth of the ground to be worked and the size of the gravel. Each bucket on the Lancha Plana dredge weighs 1,500 pounds, and there are 82 buckets in the line, giving a pitch or spacing of 24 inches. Lips are riveted to the buckets; each lip requires 15 rivets 7/8 inch in diameter and 6 of 1-1/8-inch diameter. A bucket lasts while about 1,000,000 cubic yards are dredged. The design of the lip has an important effect on its wearing qualities. To prevent bending or crushing, the arch on the lip should be in line with the back of the bucket.

Bucket pins are forged steel, 4-31/64 inches in diameter and 2 feet 8-1/2 inches long. The bucket pins are larger than the size calculated to safely carry the load because it is very desirable to reduce wear. When wear occurs on the bucket eyes, bushings, and pins, the pitch of the buckets is increased and a decrease in the effective pitch of the upper tumber takes place. With a large-diameter pin the wearing surface is greater, and hence the life of the pins and bushings is lengthened.

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The lower tumbler is round and the upper tumbler pentagonal in section. Pentagonal or hexagonal lower tumblers were used in some of the earlier dredges, probably because they were thought to give firmer seating for the buckets through their digging arc. However, after wear had increased the pitch of the buckets, this practice resulted in jerky motion and serious wear on the buckets, and modern practice is to use round lower tumblers. The upper tumbler shaft is 14-1/2 inches in diameter, with 12-inch journals. The lower tumbler shaft is 11-1/2 inches in diameter, and the journals 9-1/2 inches. The upper tumbler and shaft weigh 7 tons; the lower 4-1/2 tons.

The ladder rollers are lubricated once daily with a special grease gun. The lower tumbler is similarly lubricated, using graphite grease. The sheaves for the ladder hoist are greased with an Alemite gun.

Buckets, bucket lips, rollers, and tumblers, are made of manganese steel. The entire digging-ladder assembly weighs 125 tons. The lower or empty side of the bucket chain passes over an idler which partially supports its weight and prevents its fouling the hull of the dredge when dipping deep.

Digging Motor

The bucket line is driven by a 100-horsepower, variable-speed motor, using 440-volt, 60-cycle, 3-phase current. Its full-load speed is 580 revolutions per minute. Power is transmitted to the bucket line by belt-and-gear drive. Gears and pulleys are proportioned so that the bucket-line speed is 40 feet per minute and the buckets dig and discharge at the rate of 20 buckets per minute. To reduce torsional strain in the upper tumbler shaft the bucket drive has a gear at each end of the tumbler shaft with two series of gears driving through the intermediate shaft from the pulley shaft. Undue strains or shocks on the digging-ladder assembly or overloads on the motor when digging are avoided by the slipping of the belt drive.

Spuds and Lines

To keep the dredge in position, move it sidewise, and hold it against the bank, the boat is equipped with two spuds and four mooring lines. The two spuds at the stern of the boat slide in casings which are attached to the hull and the stern gauntry. One of the spuds is of the box type and is constructed of steel to form a hollow column 32 by 28 inches in section and 48 feet long. The other spud is made of Douglas fir 23 by 34 inches in section and 60 feet long. The wooden spud is used when the steel spud is lifted and it is necessary to "step" the boat ahead in digging. As the digging spud must withstand the bending strains caused by digging and the torsional stress caused by swinging of the boat, strength is of paramoutn importance in its design. The strength is provided by constructing the spud of structural steel. The torsional strains are reduced by equipping the spud with a shoe with a rounded point so that it offers less resistance to swinging than would a rectangular end section. The length of the spuds is determined by the digging depth and the height of the stern gauntry. The spuds are raised or lowered by

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cables which are passed to the winch over sheaves in the stern gauntry. The spuds are 12 feet apart center to center, so that a 6-foot step is easily made.

The life of a wooden hull is determined to a great extent by the wear and tear on the stern of the boat. The stern is the part which is subjected to the greatest strains due to the spud thrust. To increase the life of the hull and distribute the strains due to spud thrust more uniformly a casting is placed between the spuds and the hull so that the former can not bear directly against the hull. Through the casting the bearing strains are distributed to all the longitudinal main timbers of the dredge.

The two stern swing lines pass through deck sheaves from the winch to deadmen on shore. The two bow lines pass to sheaves on the shore and back to the toe of the digging ladder. The present swing-line sheaves are being replaced by new manganese steel sheaves, 18 and 20 inches in diameter, fitted with bronze bushings and turning on steel pins.

The cables are each 500 to 700 feet long and 7/8 inch in diameter, constructed of 6-strand, 19-wire, crucible cast steel. The average life of the cables is about 1 year. Plow-steel cables were formerly used, but these have been discarded for cables made of crucible cast steel. It is believed that the bending stress set up in the cables in passing around the sheaves is withstood better by the latter. The strength of the cables is not of primary importance as no serious damage is done if one should break.

Winch

The winch used is of the 7-drum type. Two of the drums are used for raising or lowering the spuds, 2 for the stern swing cables, 2 for the bow swing cables, and 1 for raising or lowering the digging ladder. Except for the odd drum used for the digging ladder, the drums are mounted in pairs on three shafts, and the shafts, drums, and clutches are interchangeable. The winch is driven by a direct-connected, variable-speed, 75-hp. motor. This motor runs continuously while the dredge is in operation. It is protected against overloads by the slipping of the clutches on the individual drums, and like the digging motor is provided with fuses as additional protection.

Gauntries

Near the bow of the hull is the bow gauntry, which supports the digging ladder at the outer end and carries the sheaves for raising or lowering the digging ladder. The stern gauntry supports the conveyor ladder and carries the sheaves for raising or lowering the spuds. Both gauntries are constructed of Douglas fir timbers. The bow gauntry is 32 feet high above the deck and the stern gauntry 66 feet.

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Superstructure

To afford protection from the weather for both men and machinery the dredge is inclosed by a light wooden superstructure. The pilot house is elevated considerably above the deck, as shown in Figure 2, and from this vantage point the dredge operator is able to command a clear view of the digging operations.

General Equipment

The dredge is equipped with a single-stage air compressor for operating the riveting hammer and other pneumatic tools used in making repairs. A small machine shop is maintained on the shore which is equipped with the necessary tools for doing all the minor repair work on the dredge equipment.

For night work the dredge is equipped with two 500-watt lamps placed in the bow gauntry to light the bank and the digging ladder. In addition a number of 100 and 200 watt lamps are placed at points which require illumination.

Access to the boat is afforded by a gangplank which extends a considerable distance ahead of the bow so that it can be lowered to the bank by means of a small electric hoist (see fig. 2).

DREDGING OPERATIONS

In dredging, while the digging ladder operates continuously the dredge is swung from side to side by using the winch and mooring lines. The bank is cut to an arc 70 to 80 feet wide as the dredge pivots about the digging spud. When digging near the surface the digging ladder is dropped 1-1/2 to 2 feet with each swing. This drop decreases as depth is gained, until at the bottom the distance dropped is 1/2 to 1 foot, and some swings are made with no drop. When a full cut is cleared up the ladder is raised and the second spud used to step the dredge ahead 5 or 6 feet. Some of this advance may be lost later, because the spud is likely to slip when digging in hard ground.

All digging and dredge movements are under control of the dredge operator in the pilot-house. From there he can observe the amount and character of the load in the buckets. His course is guided in part by the character of the gravel; all river gravel so far encountered has carried some gold. Examination of the gold sluices gives some indication of the amount of gold being recovered, but a clean-up is the only sure test of the value of the ground dredged.

Data on digging operations for the year 1930 are shown in the following summary.

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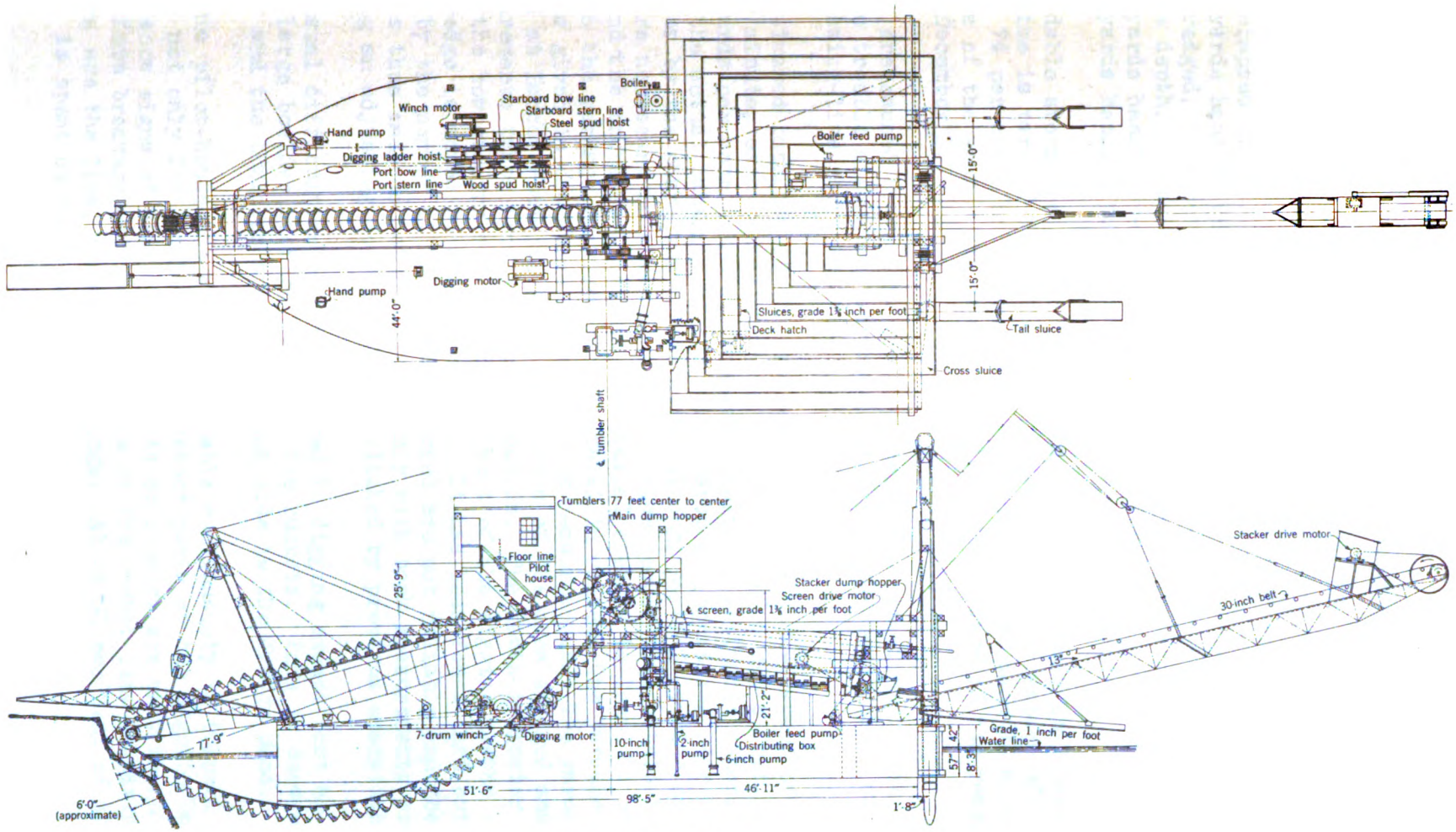

Figure 2.—Lancha Plana dredge, El Oro No. 3

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	Hours	Minutes	Per cent
Actual time dredging	5,949	15	68.29
Unavoidable stops	500	--	5.74
Delays	2,262	45	25.97
Total elapsed time	8,712	--	100.00
Cubic yards handled in year (bank measure)			731,637
Area dredged, in acres			20.795
Average depth, in feet			21.8
Cubic yards handled per calendar day			2,016
Cubic yards handled per operating hour			123

Unavoidable stops are caused by stepping ahead and clean-ups. Assuming that this time is part of the actual dredging time, the percentage of time running was 74 per cent, or 18 hours and 46 minutes out of each 24 hours for the 363 days of the year. The dredge is idle only two days of the year, July 4 and December 25.

Delays are caused by repairs and replacements of machinery, lack of power due to trouble elsewhere, moving ahead the dredge power line, and moving the swing-line shore sheaves.

The estimated capacity of the dredge, based on a bucket speed of 20 buckets per minute, each bucket carrying a full load of 6 cubic feet, is 267 cubic yards per hour. The difference between the estimated capacity of 267 and the actual capacity of 123 cubic yards per operating hour is accounted for by the character of the material dug, partial loading of the buckets, care necessary in cleaning bedrock, time required to handle large bowlders, and the increase in volume of material when it is loose in comparison with the yardage measurements of gravel in place. The yardage measurements given in the above table are bank measurements. The yardage as computed at Lancha Plana is based on surveys of the area dredged and the depth measurements taken from depth-gage records. The depth indicator is located on the bow gauntry and records are kept of the digging depths each time the dredge is moved to a new position. It has been found that estimates of yardage by the number of buckets discharged are not reliable and the measurements thus made do not check uniformly with bank measurements even though using an adjusting coefficient established by previous operations.

No unusual difficulties are encountered in digging except that an occasional large bowlder must be taken off the buckets. This is done by a chain hoist and the bowlders are cast to one side in the dredge pond.

From the pilot-house the winchman is able continuously to inspect the bucket line not only for loading, but to detect parts of the digging equipment which show signs of wear. Replacements or repairs are made whenever possible before breakage occurs. The parts of the bucket line requiring most repairs are the lips, pins, and bushings. About 60 per cent of the repair time is spent on these parts.

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REMOVAL OF OVERBURDEN

In some places the gravel is covered with a mantle of barren sand which is removed with hydraulic giants during the winter time, when water under natural head is available. In 1931, during one month 174,000 cubic yards of sand were sluiced with two 3-inch hydraulic giants at a cost of 2 cents per cubic yard. The hydraulic pipe line and ditch of a previous placer operation were used in this work. The pipe was 14 inches in diameter and made of 3/16-inch plate. The water was under a head of 80 feet, and 300 miner's inches[3] of water were available for 10 hours per day. The two giants were in actual operation 274 hours. On this basis the duty of the water was 51 yards per miner's inch per 24 hours.

GOLD-SAVING EQUIPMENT

A flow sheet of the gold-saving plant is shown in Figure 3. The gold-saving equipment on the Lancha Plana dredge consists of a revolving screen, distributor, sluices, stacker, and the necessary pumps to furnish the water for screening and sluicing.

The revolving screen is 33 feet long and 6 feet in diameter, and inclined at a grade of 1-3/8 inches per foot. It is made of 3/4-inch manganese steel plate. The holes in the screen range from 7/16-inch in diameter at the upper end to 1-inch diameter at the lower end. The holes are slightly tapered with the small end on the inside of the screen to prevent the holes from clogging. The screen is fitted with two interval rings, which retard the flow of gravel through the screen in order to increase the washing and screening time. The screen is mounted on rollers at the upper and lower ends, and is driven at a speed of 9 revolutions per minute by a 30-horsepower motor. The motor is connected by a belt drive to the rollers at the lower end of the screen. A pipe carrying 18 nozzles passes longitudinally through the screen and supplies water under pressure to wash the gravel.

The purpose of the screen is to disintegrate the gravel and clay in order to permit the fine material and the water to pass through the holes to the gold-saving sluices, and to convey the oversize material to the stacker to be carried to the waste piles. Larger holes are used in the lower part of the revolving screen on the Lancha Plana dredge so that the coarse and fine material are run into different sluices.

A distributor box catches the screen undersize and water and distributes them to the various sluices. The box is constructed of steel and runs the entire length of the screen. It has nine openings on each side, and the flow of water and gravel to the sluices through the openings is controlled by adjustable sliding steel plates. As a large proportion of the fine material passes through the screen at the upper end it is necessary to adjust the distributor outlets so that the material will be carried to the sluices at the lower end in equal quantity.

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3 - The legal definition of a miner's inch in California corresponds to a flow of 1.5 cubic feet of water per minute.

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The main sluices on the dredge are in two banks, 9 sluices in each, on both sides of the screen (see fig. 2). Each sluice is 30 inches wide and 8 inches deep, constructed of steel and set to a grade of 1-3/8 inches per foot, or 16-1/2 inches to 12 feet. The total sluice area is 2,000 square feet, including about 200 square feet in the two tailings sluices. The ordinary Hungarian or transverse riffles are used in the sluices. The riffles are 1-1/4 inches high by 1 inch wide and are made of wood covered with a riffle iron 1/8 inch thick. Riffle irons last about 10 months. The riffles are spaced 1 inch apart.

In addition to the main sluices a small sluice called the save-all is used to catch the spill from the buckets as they descend into the well. A grizzly with 2-inch openings is placed above the sluice to keep out the larger rock.

Unless the buckets dump cleanly there is a large loss of material into the dredge pond from the lower side of the bucket line. For this reason a high-pressure spray washes the buckets just below their dumping point.

Two tailings sluices extending 30 feet beyond the stern of the dredge deposit the main sluice tailings far enough to the rear to avoid grounding the dredge. The tailings sluices are of the same construction as the main sluices.

The stacker which carries the screen oversize to the waste piles extends from the stern of the dredge in line with the screen. The stacker is of the belt-conveyor type and has a length of 92 feet between head and tail pulley centers. The stacking ladder, which carries the belt, is a steel truss, pivoted at the lower end so that the height of the outer end above the water line can be adjusted. The outer end of the ladder is supported and raised or lowered by a wire rope sling from the stern gauntry. The stacker is raised or lowered by a small winch. The outer end of the stacker is kept at an elevation of about 28 feet above the water level, and the tailings piles reach a height of about 20 feet above the original surface of the ground. The stacker belt is 7-ply, having a rubber top surface of 1/4 inch at the center and 1/8 inch at the sides and a 3/32-inch rubber bottom cover. The troughing idlers are spaced on 4-foot centers. The average life of a belt in this service is about 24 months. Round bowlders are prevented from rolling back down the belt by two swinging stops placed above the belt about 30 feet apart. The stacker belt is driven by a belt-connected, variable-speed, 22-hp. motor. The motor is placed at the outer end of the stacking ladder.

The dredge uses about 3,500 gallons of water per minute. The water for screening is pumped from the dredge pond by a 10-inch centrifugal pump direct-connected to a 100-hp. motor. The additional water required in the sluices is supplied by a 6-inch centrifugal pump direct-connected to a 50-hp. motor. Both pump motors use 440-volt, 60-cycle, 3-phase current.

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GOLD-SAVING OPERATIONS

As the gravel is discharged from the buckets it passes into a steel hopper having a capacity of 15 cubic yards. From the hopper the gravel is fed continuously to the revolving screen. The screen oversize is discharged to the waste piles by the stacker and the undersize passes through the distributor into the sluices. The values are caught in the riffles and the waste is discharged into the dredge pond through the tailings sluices.

Quicksilver is added once daily to the upper ends of the sluice boxes. About three flasks of mercury are required for each 10-day period. Practically all the mercury fed into the sluices is recovered. In several clean-ups a little more mercury has been recovered than was used and this is attributed to the fact that the mercury lost in previous mining operations was recovered by the dredging operations.

Clean-ups are made approximately at the end of 10-day periods. About 70 per cent of the clean-up consists of black sands. A feature of the clean-ups is the large percentage of gold recovered near the head of the sluices and in those nearest the upper end of the screen. About 80 per cent of the gold is recovered in the first three sluices and in the upper 3 feet of each sluice. About 10 per cent of the gold is recovered by the save-all sluices, and the balance from the remainder of the main and tail sluices.

In cleaning up, the riffles are removed from the sluices, starting at the head end, carefully washing them off and washing the sluice down with water from a hose. This washes away the light sands and concentrates the amalgam and heavy sands, which are carefully scooped up into buckets and carried to a "long tom" for further treatment. In the long tom most of the mercury and amalgam and some of the platinum group metals are caught in the upper box. Most of the platinum, some rusty gold, scattered particles of mercury and amalgam, and the sand and refuse are washed out over riffles, where the heavier components are caught. The sand finally passes through a screen at the end of the tom, into a sand box, and the gravel goes to waste. The mercury and amalgam from the upper box are transferred to a bucket, in which the gold amalgam settles to the bottom; the lead or other base metal amalgams float on top. The latter is partially cleaned by panning, which separates some metallic platinum, then retorted. The gold amalgam is squeezed free of mercury, and likewise retorted.

The gold amalgam, usually containing about 55 per cent gold and silver, is retorted in a standard make of gasoline-fired retort. The mercury condenses in a water-jacketed pipe and drains into a bucket of water. The gold remaining in the retort is transferred to a crucible and fused in the same furnace. It is then poured into molds, producing bars which are shipped to the Selby smelter. The bullion averages 890 parts gold, 90 parts silver, and 20 parts impurities per 1,000.

The riffle concentrates and sand from the end of the long tom are placed in small batches in a steel barrel mill 4 feet long and 2-1/2 feet in

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diameter. Mercury is added and the batch ground for 1 or 2 hours. Then the amalgam is removed by panning, and added to the other base amalgam for retorting. Further panning and rocking reduce the remaining sand and concentrates to a product containing about half black sand and half platinum, by volume. This is treated by the addition of water, mercury, zinc shavings, and sulphuric acid; this causes the platinum metals to be coated and held by the mercury, so that a final separation from the sand is possible. The final concentrate is then washed with water and drained to remove acid and excess mercury, after which treatment with nitric acid dissolves the mercury, leaving a final residue of platinum, iridium, and osmium.

The base amalgam, which includes shot, bullets, and small particles of copper and brass scrap, as well as some precious metals, is retorted to recover the mercury, melted, and poured into molds to form bars for shipment to the smelter. These bars range in value from $1 to $8 per Troy ounce.

PREVENTION OF STREAM POLLUTION

To prevent the sediment from dredging operations from entering the Mokelumne River, the overflow from the dredge pond is directed to settling ponds. The silt settles in the ponds and the overflow water is allowed to escape to the river. In making the settling ponds natural surface depressions are used as much as possible, and where necessary the banks are built up with a drag-line scraper operated by a 2-drum hoist mounted on a tractor.

WATER SUPPLY

About 2,000 gallons of new water per minute are required to maintain the level of the dredge pond. This water is pumped from the Mokelumne River by a 10-inch centrifugal pump direct-connected to a 40-horsepower motor. The water is elevated about 45 feet to a ditch through which it flows to the dredge pond. The ditch is about 1/2 mile in length and trapezoidal in section, averaging 4 feet wide at the top and 2 feet at the bottom. The average depth of the ditch is about 2 feet. The ditch was excavated by a Simplex ditcher and tractor.

The water is impounded without difficulty, as the tailings piles and bedrock are practically impervious to water. The elevation of the dredge pond at the present time is 27 feet above the river level, but this is variable and dependent on the surface and bedrock elevations. Where the depth of the ground being worked is from 20 to 45 feet the water surface is maintained at 4 to 8 feet below the ground surface, but in deeper digging it will be necessary to keep the water surface as much as 20 feet below the top of the bank.

POWER

Power is obtained from the Pacific Gas and Electric Co. at an average cost of 1.1 cents per kilowatt-hour. According to the power schedule the cost of power varies with the amount used, and there is also a minimum

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monthly demand charge which averages about $250. The power is transmitted from shore to dredge at 4,000 volts by means of an insulated armored cable, and there stepped down to 440 volts by a bank of three 100 kilovolt-ampere transformers. The power cable, 3/4-inch in diameter, weighing 4 pounds per foot, has an estimated life of 3 to 4 years.

All motors on the dredge and on shore operate on 3-phase, 440-volt current. The various motors, the capacity of each, and the type of drive, are listed below.

Where used	Horsepower	R.p.m.	Type of drive
Digging motor	100	var.	Belt
10-inch centrifugal dredge pump	75	1,200	Direct
6-inch centrifugal dredge pump	50	1,200	Do.
Swing-winch motor	75	var.	Do.
10-inch centrifugal shore pump	40	900	Do.
Air-compressor motor	50	900	Belt.
Stacker-drive motor	22	var.	Do.
Screen-drive motor	30	850	Do.
Fire-pump motor	20	1,120	Direct
Shop motor	5	1,200	Belt
	467		

DREDGE CREW

The following tabulation gives the average crew required to operate the dredge on a 24-hour-day basis.

Classification	Rate per day	Total
3 winchmen	$6.00	$18.00
3 oilers	5.00	15.00
1 bank man	5.00	5.00
1 shoreman	7.20	7.20
1 man on settling ponds	5.00	5.00
9		50.20

In addition to the above crew are a superintendent and a bookkeeper.

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Table 1. - Summary of costs per cubic yard

Number of dredges: 1
Cubic yards handled: 731,637 (bank measure)
Period: Year of 1930

	Cost per cubic yard
Labor:	
Operation of dredge	$0.02787
Repairs	.00518
Water supply	.00020
Prevention of stream pollution	.00052
Miscellaneous	.00000
Total labor per cubic yard	0.03377
Power:	
Operation of dredge	0.01789
Pumping water for dredge pond	.00200
Total power per cubic yard	0.01989
Supplies:	
Operation	0.00580
Repairs	.03587
Total supplies per cubic yard	0.04167
Supervision	0.01716
General expense, office, building roads, etc.	.01143
Taxes and insurance	.00454
Prospecting and sampling	.....
Amortization or depreciation of equipment	.01810
Total cost per cubic yard	0.14656

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Table 2. - Summary of costs in units of labor, power, and supplies

Number of dredges: 1
Cubic yards handled: 731,637 (bank measure)
Period: Year of 1930

	Man-hours per cubic yard
Labor:	
Operation of dredge	0.03971
Repairs on dredge	.00752
Water supply	.00029
Prevention of stream pollution	.00072
Miscellaneous	.00000
Total man-hours per cubic yard	0.04824
	Kilowatt-hours per cubic yard
Power:	
Operation of dredge	1.79
Pumping water for dredge pond	.09
Total power per cubic yard	1.88
Other supplies in percentage of total power and supplies	64.8
	Percentage of total cost
Labor	23.1
Power	13.6
Supplies	28.4
Other expenses	34.9
	100.0

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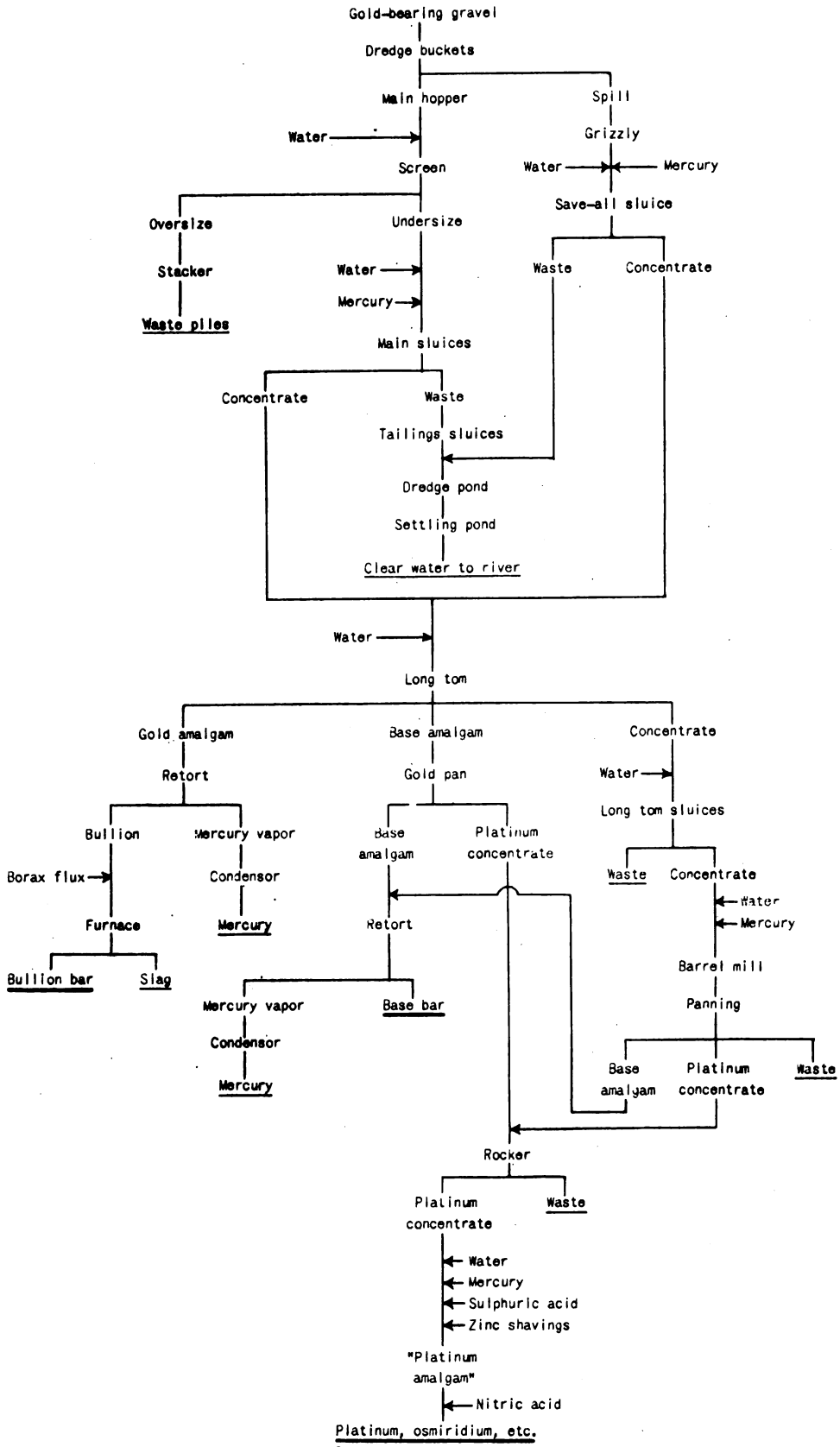

Figure 3.- Flow sheet of Lancha Plana dredge

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